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PCB Field Test Kit Volume II: Method Development/ Testing

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| <p>This technical report has been prepared in two volumes for two specific audiences. Volume I, Field Testing, is intended for persons with no formal laboratory background such as exterior electricians who could perform sampling and testing procedures on transformers, oil circuit breakers, etc., as part of their maintenance duties, and civil engineering personnel who must clean up spill sites. Consequently, Volume I is concerned with how the test is run and how a site is surveyed vs. how the test works and gives cleanup hints and suggested procedures for testing and finding PCB contamination with little emphasis on method development. Only those data necessary to confirm the kit performance are given.</p> <p>Conversely, Volume II, Method Development/Testing, is intended for use by policy makers who must determine whether or not the kit is appropriate for their organization. As a result, Volume II emphasizes the development of the extraction method, the verification testing for the oil kit, and the data collected during soils testing. The information</p> | | | |
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given is meant to serve as a basis for policy decisions with field procedures, spill analysis, and actual cleanup techniques of minor importance.

In either case, Volume I or II, the reports are written to stand alone and need not be read in conjunction with each other.

Soil analysis for polychlorinated biphenyls (PCBs) is a well-established laboratory procedure; however, until recently, the field methods were too complex for nontechnical personnel. Without a simplified test, Air Force cleanup crews working in field situations were seriously hampered. This was the situation with the Alaskan Air Command's efforts to cleanup soil inadvertently contaminated with PCBs at the abandoned White Alice Communication System (WACS) sites.

To provide a simplified field test for PCBs, the Air Force Engineering and Services Laboratory (ESL), Air Force Engineering and Services Center, coupled a commercially available analyzer for transformer oils containing PCBs with its own extraction procedure. The result was a PCB field test kit which enabled field teams to perform semiquantitative tests for PCBs in oils or soils, in 5 minutes, for \$5 per test. In addition, the test kit can analyze "swipe samples" as well as leaves, grass, etc., by extracting the PCB from the sample, measuring the PCB in the extract, and then converting that concentration to a microgram equivalent.

The kit development emphasized finding a field tool for non-laboratory-trained personnel to use in measuring PCB concentrations. The kit is not a replacement for EPA-recognized analytical techniques for PCB measurement in that it cannot differentiate between PCBs and any other organic chloride (e.g., trichloroethylene). To have provided that degree of accuracy and specificity would have defeated the purpose of developing a field method. Instead, the kit compliments standard laboratory techniques by categorizing the contamination in oil or soil samples per the levels set in the EPA regulations.

The kit does have a semiquantitative capability, which adds to its value as a field tool. The ability to approximate contamination levels is useful in mapping a spill area to determine the level of cleanup effort required.

The kit is commercially available as a GSA-listed item and the device is being added to Air Force Table of Allowances TA-486.

PREFACE

This technical report was prepared by the Headquarters, Air Force Engineering and Services Center (AFESC), Engineering and Services Laboratory, as an in-house research project under JON 20543046. The objective was to develop a field method for analyzing soils contaminated by polychlorinated biphenyls (PCBs). The research was performed by the Environmental Engineering Branch of the Environics Division (HQ AFESC/RDVW).


The research was performed between January 1983 and March 1984 and included both development and verification of a field analytical method for soil samples and verification testing of a commercially available field test kit for analyzing PCB oil samples. AFESC Project Officer was 1Lt James R. Aldrich.

This report has been reviewed by the Public Affairs Office (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS it will be available to the general public including foreign nationals.

This technical report has been reviewed and is approved for publication.



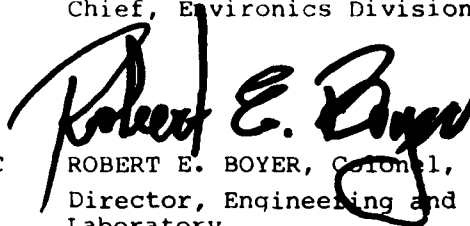
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SECTION I

INTRODUCTION

OBJECTIVE

This research effort was established to find or develop a nontechnical, field method to enable PCB cleanup crews to find soils contaminated by polychlorinated biphenyls (PCBs) and determine when cleanup is complete.

BACKGROUND

The nation's security during the Cold War 50s depended on the ability to detect and react to hostile air attack. Part of this detection capability was the responsibility for early warning radar systems such as the DEWLINE, and their supporting communications networks, such as the White Alice Communications System (WACS). Although these systems were effective, the ground-based radar systems of the 50s were replaced with rapid advances in satellite communications and the WACS became obsolete. By the end of the 70s, these 69 individual WACS sites had either been shut down or turned over to civilian communications firms such as ALASKCOM. Unfortunately, and unwittingly, when these communications sites were abandoned, an "alligator was left in the swamp," that of PCB-contaminated soils.

The WACS was a technology of the late 40s and early 50s. Its age and criticality to the nation's defense, combined to create this hidden problem. Being an old technology, the WACS had a very large power requirement with as many as 35 transformers located at any one site. Second, since the sites had a primary wartime mission, a great deal of redundancy was built into both the individual sites, as well as the overall network. If one element of a site such as a generator, or an entire site was eliminated by an attack, the communications channels could be rerouted, preserving the communications link. In addition, the maintenance requirements for the system were such that the dielectric oils used to insulate and cool electrical equipment, such as transformers, were sampled and analyzed regularly for component breakdown and dielectric constant. It was this standard operating maintenance procedure that actually caused the problem. After the maintenance testing was done, and the oil samples were analyzed these samples were thrown away in any convenient manner. Unfortunately, these oil samples were often contaminated with polychlorinated biphenyls (PCBs).

It must be emphasized that at the time the WACS was in use, PCBs were not recognized as environmental contaminants. Instead, they were the state of the art in dielectric coolants and were used almost exclusively by both the civilian and military industries. PCBs were so common that the National Academy of Sciences estimates over a billion pounds have been distributed in the United States alone. In fact, the only problem PCBs presented during the WACS era was that if PCB oil was poured down a sink, the heavier PCB portion would collect in the drain traps and clog the plumbing. In turn, the oil samples were often thrown on the ground outside the buildings because more intricate disposal methods were not required.

Since that time, research has linked PCBs to a variety of physical problems such as liver disease and it is a suspected carcinogen. In addition, PCBs have a tremendous stability and resistance to breakdown in the environment. These two factors, toxicity and stability, led the EPA to officially ban the use of PCBs which ultimately forced the AAC to return to all of these abandoned communications sites and remove soil inadvertently contaminated.

THE ALASKAN AIR COMMAND'S WACS CLEANUP PROGRAM

Removing the PCB-contaminated soil is relatively simple. First, it is located, then removed. In fact, there are only two real problems in the entire procedure; first, how to locate the PCB-contaminated soil, and second, how to remove it.

The problem in removal is getting crews and equipment to the WACS sites. The 38 sites currently on the cleanup list range over 6000 miles of Alaskan wilderness. To put this in perspective, Figure 1 shows a map of Alaska, superimposed over a map of the CONUS states, both drawn to the same scale where the sites are shown as dots.



Figure 1. The White Alice Communication System (WACS)

The cleanup crews, dispatched from Elmendorf AFB, (about where St. Louis would be), are responsible for sites ranging from Orlando, FL to Los Angeles, CA, to Duluth, MN and most areas between. In addition to the distances involved, very few of these sites are linked by roads and of these, the site crews were responsible for road maintenance. In turn, when the sites were closed in the late 70s, road maintenance halted. This

problem also applies to the landing strips and site access roads. To understand how this affected the AAC cleanup efforts, a miniscenario for cleaning up a site, accessible only by air, is presented.

First, a light plane is dispatched with a survey crew to scope the work required at the site. Then a repair crew would come in to improve the landing strip so that either a C-130 or L-100 loaded with light equipment could land. After this initial repair was complete, heavy equipment: bulldozers, dump trucks, backhoes, etc., could be brought in to rework the road from the landing strip to the site. Finally, the cleanup crew was ready to start removing the PCB-contaminated soil. After the soil was excavated and drummed, everything had to be airlifted from the site to the main base. Logistics was then a major task and by far the most expensive problem faced by the AAC; however, it was manageable. On the other hand, finding the PCB-contaminated soil and determining whether it had all been removed was more crucial to the success of the effort.

Again, a miniscenario is presented, but from the PCB contamination standpoint, rather than logistics. As before, the survey crew was first on site. Their task was to scope the work required. In addition to getting soil samples for PCB analysis, they logged the volumes and types of hazardous wastes to be removed (such as PCB oils, solvents, and MOGAS) and recorded the solid wastes requiring disposal (such as abandoned equipment and empty 55-gallon drums). After they left the site, the collected soil samples were shipped to a laboratory and analyzed and the results were built into a "PCB Map" of the site for the cleanup crews. For example, Figure 2 shows the survey map prepared from the survey of the Fort Yukon WACS site.

At first glance, this map, along with a listing of volumes of hazardous waste, numbers of empty barrels, etc., would seem to be sufficient; however, a number of questions still had to be addressed.

1. Did microgram (μg) mean anything to a backhoe operator? Was it microgram per liter? per kilogram? per square foot?
2. Where exactly was each sample taken?
3. Were the soil samples composites of a 2-foot by 2-foot area? A 6-foot by 6-foot area?
4. Were the samples taken from directly in front of a door? Was the area sampled with depth? Was the left side of the door composited with soil from the right side?

These questions may seem "picky," but when the backhoe operator needs to know exactly where the first shovel full of dirt should be taken, or when he can stop digging, the answers are critical.

If the map was inadequate, why was it not changed? It was the best job that could be done with the tools available in the field. How could the survey crew define a hot spot if their test results were not available until weeks after they had left the site? With the only laboratory in Alaska hundreds of miles from the site, a more comprehensive survey was nearly impossible.

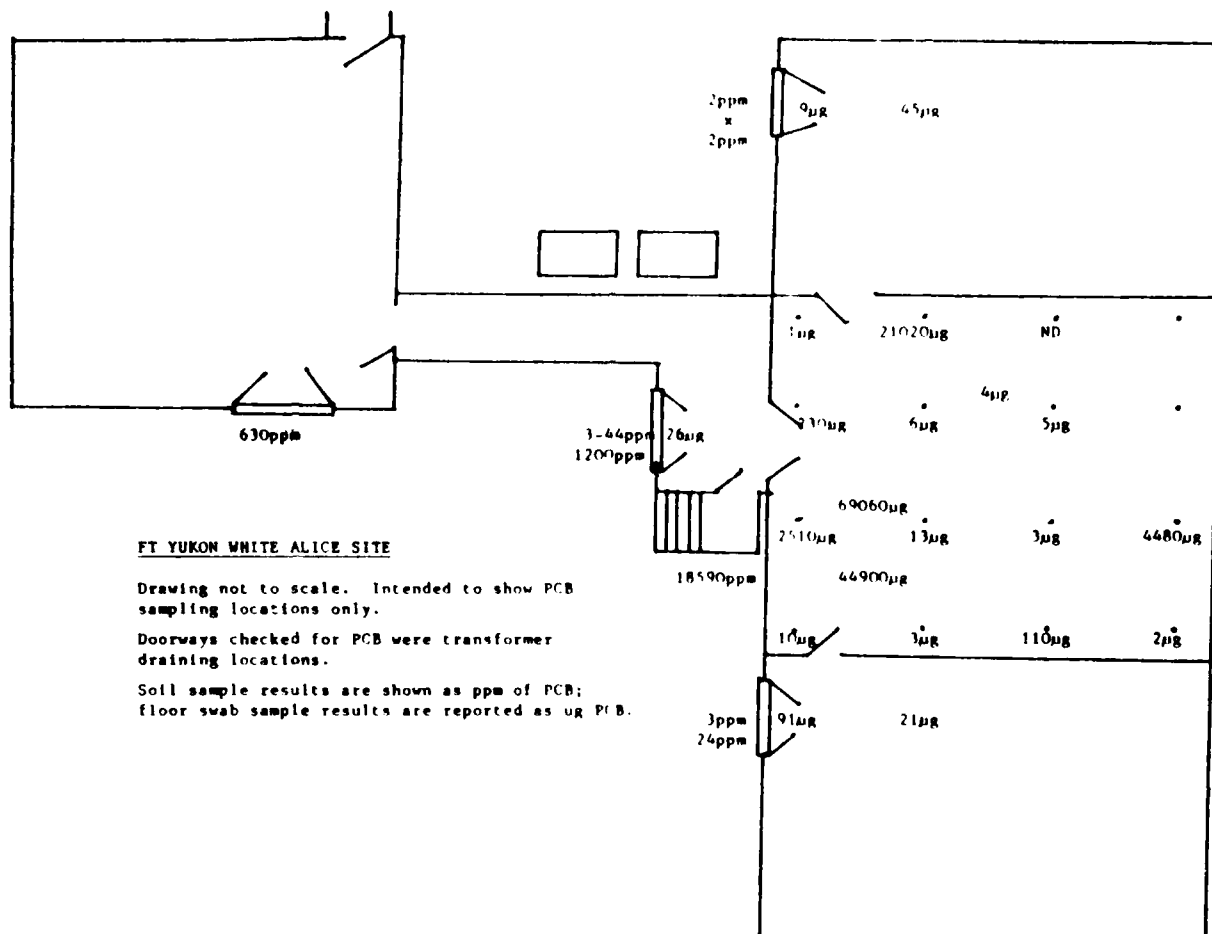


Figure 2. The "PCB Map" of the Fort Yukon WACS Site

Even if the distance problems could have been solved and the cleanup crews been provided a more extensive map, there would still have been the problem of determining when the cleanup was complete. Since a recovery drum filled with soil weighs approximately 1300 pounds and must be airlifted from the sites, indiscriminate removal of possibly contaminated soil was a very expensive alternative; however, the alternative was to not remove all of the contaminated soils on the first visit. If this happened, the crews would have to return to the site for more work. Given the \$50,000 to \$80,000 airlift costs just to move the crew and equipment, revisiting sites for more work was no more viable than indiscriminate digging.

The AAC, thus, faced a "no-win" situation; not only was it difficult to find the PCB-contaminated soil, the crews needed to know that their work at a site was complete. Without this information the AAC was left only the very expensive alternatives of either incomplete cleanup or "overkill."

SECTION II

THE EXPERIMENTAL PROGRAM

SOIL TEST REQUIREMENTS

The first step was to define exactly what the PCB crews needed and what the soil test would have to provide. This posed two questions: (1) Although standard laboratory techniques would serve to measure PCB, was that level of complexity needed? (2) Did the field crews need to measure PCB soil contamination, or simply categorize the concentration present in the soil? The distinction between measuring and categorizing became the key issue in developing the research program.

The Environmental Protection Agency (EPA) regulations do not mandate exact measurements of PCBs such as 98.3 parts per million (ppm). Instead, cleanup and disposal requirements are based on the PCB contamination ranges shown in Figure 3.

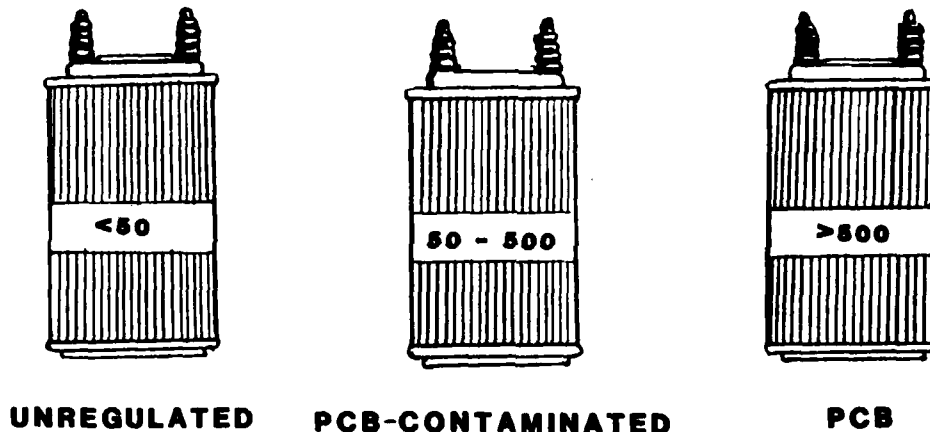


Figure 3. EPA Concentration Ranges for PCB Oils (in ppm).

While providing the AAC's field crews with a full analytical capability would solve their problem, all they really needed was the much simpler capability to categorize PCB contamination.

Although the ranges shown in Figure 3 are for oils, similar limits exist for PCB-contaminated soils. For example, in Alaska, there was no requirement to know whether or not a soil sample contained exactly 98.3 ppm PCB. Instead, because PCB concentrations under 50 ppm were unregulated, it was that level that triggered cleanup actions.* Any PCB soil concentration over 50 ppm required cleanup; any concentration under 50 ppm could be left alone.

*50 ppm was selected as the cutoff point for this project because that was the requirement levied against the AAC by the State of Alaska. Given the detection capability of the kit, lower limits could be set and quantified.

Hence, the analytical capability required of the field test was defined; the kit needed to quantify soil samples as either contaminated (over 50 ppm PCB) or clean (under 50 ppm). Although the AAC had other requirements for the kit such as portability, power requirements, availability of test reagents, etc.; the 50 ppm detection was the key to the project.

HARDWARE CRITERIA

Commercially available "test kits" were first checked to see if any met the needs of the cleanup crews. Although none were capable of testing both oils and soils, a number of oil analyzers were available. The test methods examined included a variety of field techniques ranging from simple test tube kits to elaborate, portable gas chromatographic units with dedicated computers. Four criteria were applied in evaluating each kit:

1. Since the cleanup crews were normally heavy equipment operators, the test method had to be simple enough for personnel with no laboratory training.

2. The device had to yield a simple analytical result with a minimum of data interpretation. Again, a heavy equipment operator could not be expected to interpret a GC strip chart.

3. Because the extraction efficiency of PCB from soil was not consistent with respect to various soil types, the oil analyzer selected needed a flexible, quantitative output vs. a simple qualitative, "go/no-go" indicator.

4. The device, with modifications, would have to accurately categorize PCB concentrations in soils according to the state-imposed criteria. Because the project became one of adapting an oil analyzer, the selected analyzer would also have to be investigated with respect to accuracy in categorizing oils.

KIT SELECTION

Except for the GCs, most devices evaluated relied upon a chemically induced color change much like the chlorine residual test used for swimming pools. Devices based on this method were eliminated because they were tied to a specific PCB concentration (generally around 35 ppm PCB) to trigger the color change. This method forced the operator to interpret the color change and made determining how hot the sample was (e.g., over 50 ppm, 500 ppm, or 5000 ppm) impossible to determine in one test. Given the changing hardware disposal requirements for oils over 500 ppm and the variability of PCB soil extraction, these colorimetric devices were of limited use.

One kit however, provided a digital millivolt response (e.g., 81 millivolts). Since having a number minimized data interpretation and made it easy to incorporate safety factors and other allowances needed for the soil test, this kit was selected as the measurement device.

The kit selected works on a very simple principle. The PCB is first mixed with a strong sodium solution which forms sodium chloride: table salt. The salt is then dissolved in water and the chloride concentration is checked electronically.

All that the operator needs to do is read a number off the machine. In addition, the chemistry of the reaction made it very difficult to miss any PCBs. One drawback was that it would react with any chlorinated organic molecule present in the test sample. The PCB could be overestimated, but would not be missed.

SECTION III

SOIL TEST DEVELOPMENT

With an oil analyzer selected, attention shifted to developing a simplified field extraction method. Standard laboratory extraction methods, Soxhlet extraction and agitation, were considered. The first method, Soxhlet, which involves heating a flammable solvent, was eliminated because of the inherent dangers to an inexperienced operator. Simplifying the agitation extraction then became the crux of the project.

TEST SOILS

Initially, three soil types were selected for study, covering the factors most likely to control extraction efficiency. The soils ranged from a clay subsoil to a black, humic topsoil. To simulate field conditions, the soils were neither dried nor sterilized before testing. In this manner, bacterial degradation of the PCBs would not be inhibited. Each soil was spiked with the following initial concentrations of PCB as Arochlor 1260: 0 (control), 15, 30, 50, 75, 250, 500, 750, and 1000 ppm.

The soil selection and initial spiking levels would show the effects of PCB concentration and soil type. Other variables investigated with respect to extraction efficiency were soil sample size, agitation time, and solvent/soil mass ratio. For these initial tests, one of the standard laboratory agitation methods (ASTM D3304-77) was simplified and established as the Engineering and Services Laboratory (ESL) method. It consisted of mixing soil and hexane in a 25-milliliter sample vial and shaking the mixture by hand for a set time. The results of these first runs are shown in Figures 4 and 5. All data are expressed as a percent recovery of PCB (on the "Y" axis) vs. the indicated variable (on the "X" axis).

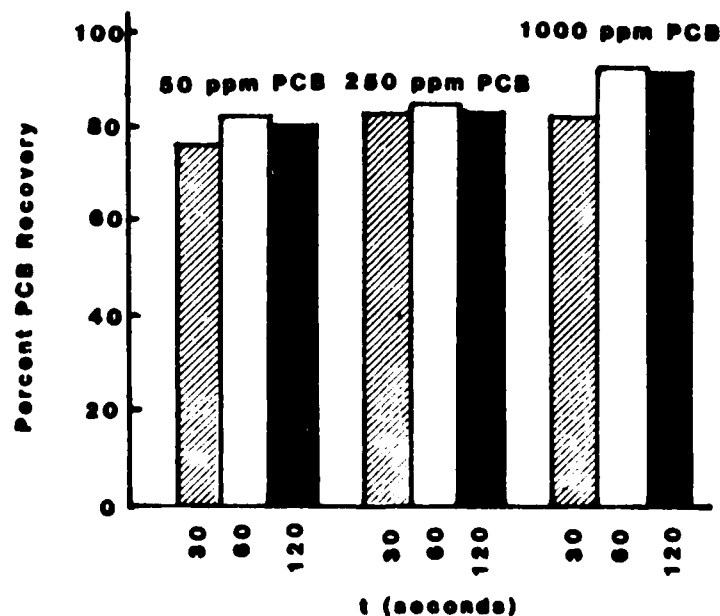


Figure 4. Agitation Time and Initial PCB Concentration vs. PCB Recovery

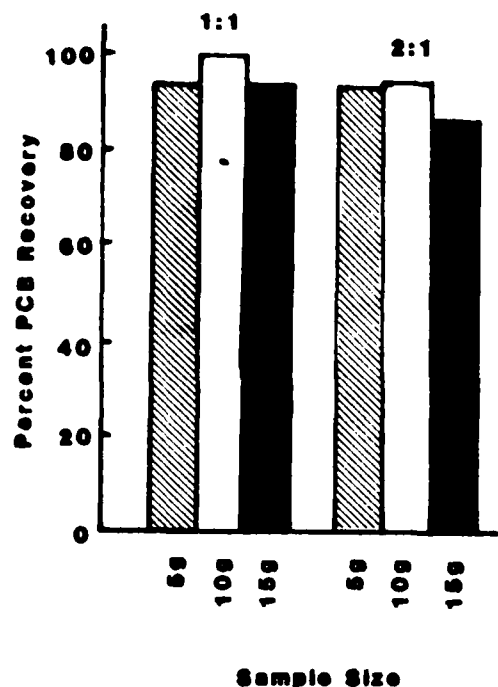


Figure 5. Solvent/Soil Ratio and Soil Sample Size vs. PCB Recovery.

Although the new ESL extraction method did not remove all of the PCB from the soil (i.e., the efficiency shown on the graphs was less than 100 percent), the extraction percentage was consistent. This consistency meant a minimum extraction efficiency could be set and PCB concentrations could be mathematically scaled. For example, if the new method consistently measured only one-half the PCB present in a soil sample, doubling the test results would compensate for the inefficiency.

As a result of these tests, the final ESL extraction method was established as taking approximately 5 grams of soil, mixing it with an equal mass of hexane, and shaking it for 30 seconds. The soil extract would then be analyzed with the kit in the same manner as an oil sample.

TEST MATRIX

A test matrix was established to verify the new method. Each soil sample was split and extracted by both the standard laboratory (ASTM) and new field extraction (ESL) methods and then both extracts were analyzed for PCB, using the field kit and conventional laboratory (GC) techniques. The test matrix, shown in Figure 6, could be used to compare any part of the new method, either the new extraction or kit measurement, to standard techniques. For example, test results from pathway ABC vs. ABC' would correlate the two measurement methods.

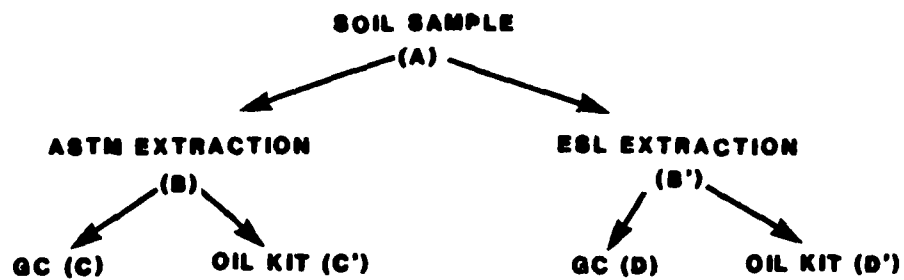


Figure 6. The Soil Test Matrix

SECTION IV

DATA INTERPRETATION

Before the testing began, the manufacturer's method of converting the kit's digital, millivolt readout, to a PCB concentration was simplified. The kit's digital millivolt response appears much like Figure 7.



Figure 7. The PCB Kit Digital Millivolt Readout (e.g. 81 millivolts).

To convert this readout to a PCB concentration, the manufacturer provides two PCB oil equivalency tables with the kit, one for Arochlor 1242 and one for Arochlor 1260; part of the 1260 table is shown in Figure 8.

Equivalency Table

| | | (Continued) | |
|------------------------|----------------------|------------------------|----------------------|
| Probe Response (mV) | ppm PCB (as 1260) | Probe Response (mV) | ppm PCB (as 1260) |
| 120 | 6 | 60 | 59 |
| 118 | 6 | 58 | 64 |
| 116 | 7 | 56 | 69 |
| 114 | 7 | 54 | 75 |
| 112 | 8 | 52 | 81 |
| 110 | 9 | 50 | 88 |
| 108 | 9 | 48 | 95 |
| 106 | 10 | 46 | 102 |
| 104 | 11 | 44 | 111 |
| 102 | 12 | 42 | 119 |
| 100 | 13 | 40 | 129 |
| 98 | 14 | 38 | 139 |
| 96 | 15 | 36 | 151 |
| 94 | 16 | 34 | 163 |
| 92 | 17 | 32 | 176 |
| 90 | 19 | 30 | 190 |
| 88 | 20 | 28 | 205 |
| 86 | 22 | 26 | 222 |
| 84 | 23 | 24 | 240 |
| 82 | 25 | 22 | 259 |
| 80 | 27 | 20 | 280 |
| 78 | 30 | 18 | 303 |
| 76 | 32 | 16 | 327 |
| | | | |
| 74 | 35 | 14 | 353 |
| 72 | 37 | 12 | 382 |
| 70 | 40 | 10 | 413 |
| 68 | 44 | 8 | 446 |
| 66 | 47 | 6 | 482 |
| 64 | 51 | 4 | 521 |
| 62 | 55 | 2 | 563 |
| | | 0 | 608 |
| | | -2 | 657 |

Figure 8. The Equivalency Table for Arochlor 1260.

The problem in using these tables is that an operator may have no idea which oil (1242 or 1260) they are testing, and soil testing requires an additional scaling step. To simplify this process for the operator, the Engineering and Services Laboratory developed a wheel similar to a circular slide rule, to interpret the millivolt response. The wheel, set for oil samples, is shown in Figure 9.

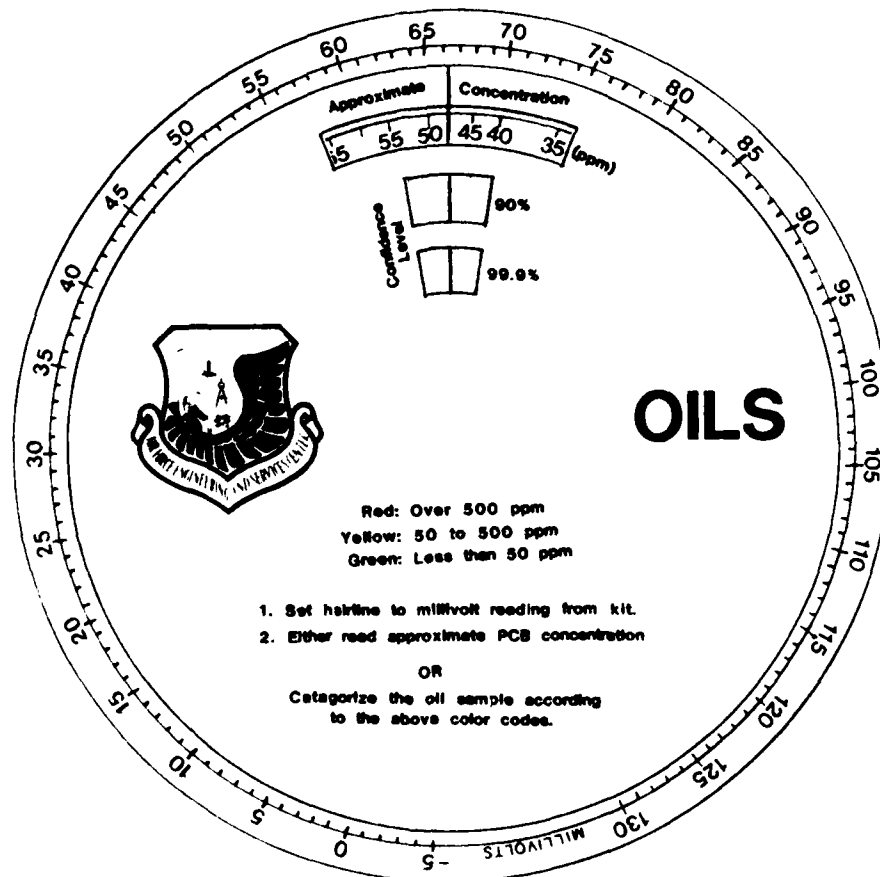


Figure 9. The ESL Wheel for Converting Millivolts to a PCB Concentration

With the wheel, all the operator needs to do is to set the hairline to the millivolt readout from the kit and read the PCB level by looking at the color that shows through the confidence limit windows. Because the EPA regulations specify categorizing oils, the wheel is based on this same principle: if red showed through the window, the oil concentration would be over 500 ppm; yellow, the concentration would be between 50 and 500 ppm; green, below 50 ppm. Two separate confidence limit windows were included to cover the most common oil types; the 90 percent confidence limit roughly corresponds to Arochlor 1260 (and other common oils such as Askral and Pyranol) and the 99.9 percent confidence limit corresponds to Arochlor 1242. The difference is in the chloride contents of the two oil types; Arochlor 1242, from an analytical standpoint, is the "worst case." However,

the decision of which confidence limit to use would be made by the environmental staff (e.g., the environmental coordinator) rather than in the field.

SECTION V

OIL TEST RESULTS

ANALYTICAL COMPARISON

The key to the entire research project was whether the kit could accurately measure and categorize soils and oils contaminated with PCB according to EPA criteria. In evaluating the field kit on oil samples, nearly 1000 kit tests were run side-by-side with standard laboratory testing by five separate laboratories. Four of these laboratories tested random oils (either submitted for analysis, or sampled specifically for these tests) and one used oil samples spiked to particular PCB concentrations. Figure 10 shows how well the kit compared to laboratory testing under the criteria of proper classification of the oil samples according to EPA criteria, i.e., over 500 ppm, under 50 ppm, or in between, and using the 90-percent confidence limit on the ESL wheel.

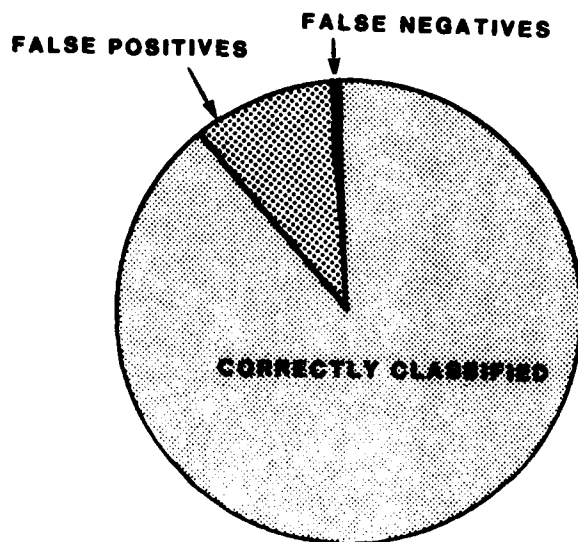


Figure 10. Oil Test Results from the Kit vs. GC
(90-Percent Confidence Limit).

As Figure 10 shows, even when the less conservative (90-percent) confidence limit was used, only 0.5 percent of the samples tested yielded false negative results, i.e., oils classified too low. They would be eliminated by increasing the safety factor by using the 99.9-percent confidence limit; however, this would also increase the number of false positive (artificially high) answers. Figure 11 demonstrates this increase graphically by interpreting the same test results as Figure 10, except using the higher (99.9-percent) confidence limit.

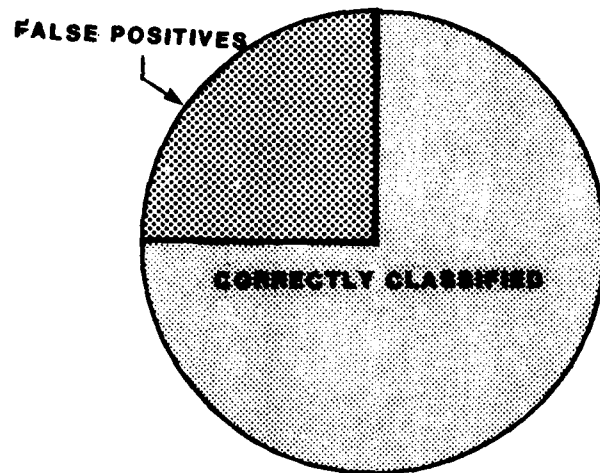


Figure 11. Oil Test Results from the Kit vs. GC
(99.9 Percent Confidence Limit)

CONFIDENCE LIMIT SELECTION

Three factors must be considered in deciding which confidence limit to use. First, in the oil samples examined, Arochlor 1260 type oils (including Askral) were most often used in transformers (the 90-percent confidence limit), and Arochlor 1242 type oils were most often used in capacitors (the 99.9-percent confidence limit). Second, as shown in Figure 12, the PCB concentrations found in the cooling oils can influence the decision. (Note: Only the random oils are shown in Figures 12 and 13).

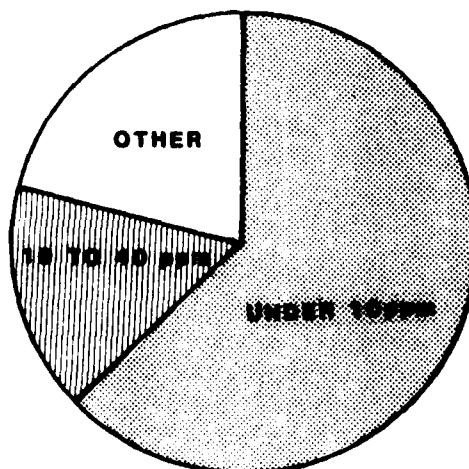


Figure 12. PCB Concentrations from the Random Oil Samples.

Next, the number of random oil samples close to the critical cutoff points of 50 and 500 ppm is important. Figure 13 emphasizes these critical ranges.

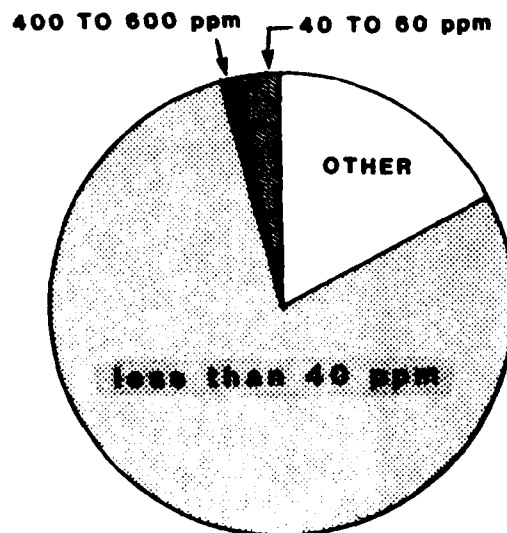


Figure 13. The PCB Concentrations Near the Critical Ranges.

Two key conclusions can be drawn from these last two figures. First, over 75 percent of the 700 random oil samples contained less than 40 ppm PCB and nearly 65 percent were under 10 ppm. Second, very few of the samples fell within ± 20 percent of the critical cutoff points; only 3 percent were in the 40 to 60 ppm range and only 1 percent was in the 400 to 600 ppm range. This makes the probability of a false negative answer under these conditions even smaller.

The final consideration is EPA requirements which allow all oils to be disposed as "worst case" (over 500 ppm PCB), without analysis. At least conceptually, this is the same as using an analyzer with a 100-percent false positive analysis rate. This can be reduced to either 25- or 10-percent false positives with the kit (i.e., the 99.9- or 90-percent confidence limit) and conventional laboratory techniques can reduce this even further.

OIL TEST COST COMPARISON

Economically, the field kit can be easily compared to the alternate methods. Ignoring the advantage of having test hardware on-hand, the economic breakdown is as follows. Assuming that two out of every five tests are on soil samples (based on the Alaskan surveys as well as other sites), Figure 14 shows the cost per analysis using the kit, standard laboratory techniques (based on \$50 for an oil sample and \$80 for a soil sample) and one of the "test tube" kits at \$8 apiece.

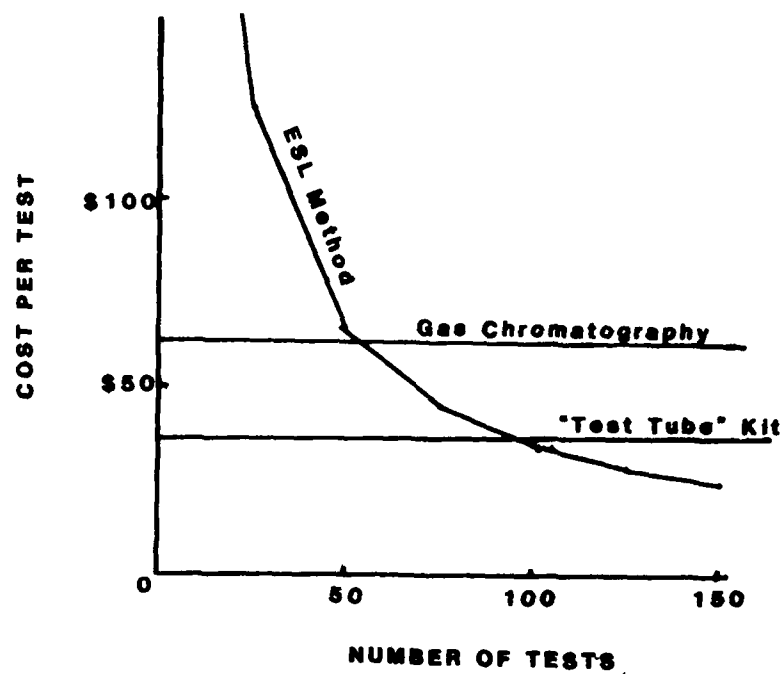


Figure 14. Cost (per test) Comparison of Three Measurement Alternatives.

As the figure shows, the break-even point is approximately 100 tests. If a similar graph were shown under the assumption that only one of five tests would be a soils test, the break-even point would be at approximately 200 tests. If no soil samples were considered, the test costs would be as shown in Figure 15.

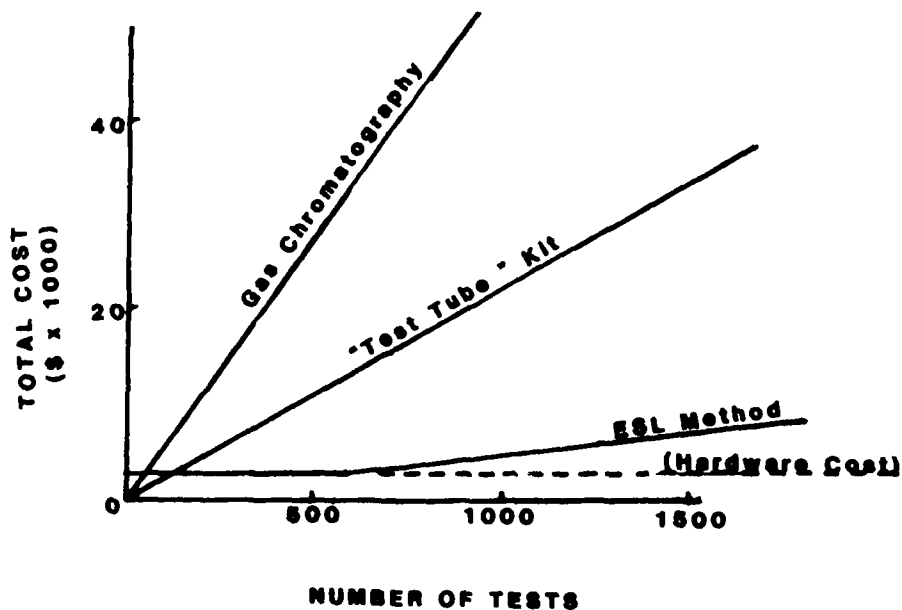


Figure 15. Cost (Total) Comparison of Three Measurement Alternatives.

SECTION VI
SOIL TEST RESULTS

FIELD EXTRACTION COMPARISON

The soil test results can be broken into three distinct categories. First, a comparison of the new field extraction method vs. standard laboratory techniques; second, using the kit vs. GC to measure the PCB concentration in the soil extract; and, finally, a comparison of the entire field method to standard laboratory techniques. Figure 16 starts these comparisons by examining the extraction method. All three soil types were extracted by both the field and standard lab methods and the PCB concentrations then determined by GC.

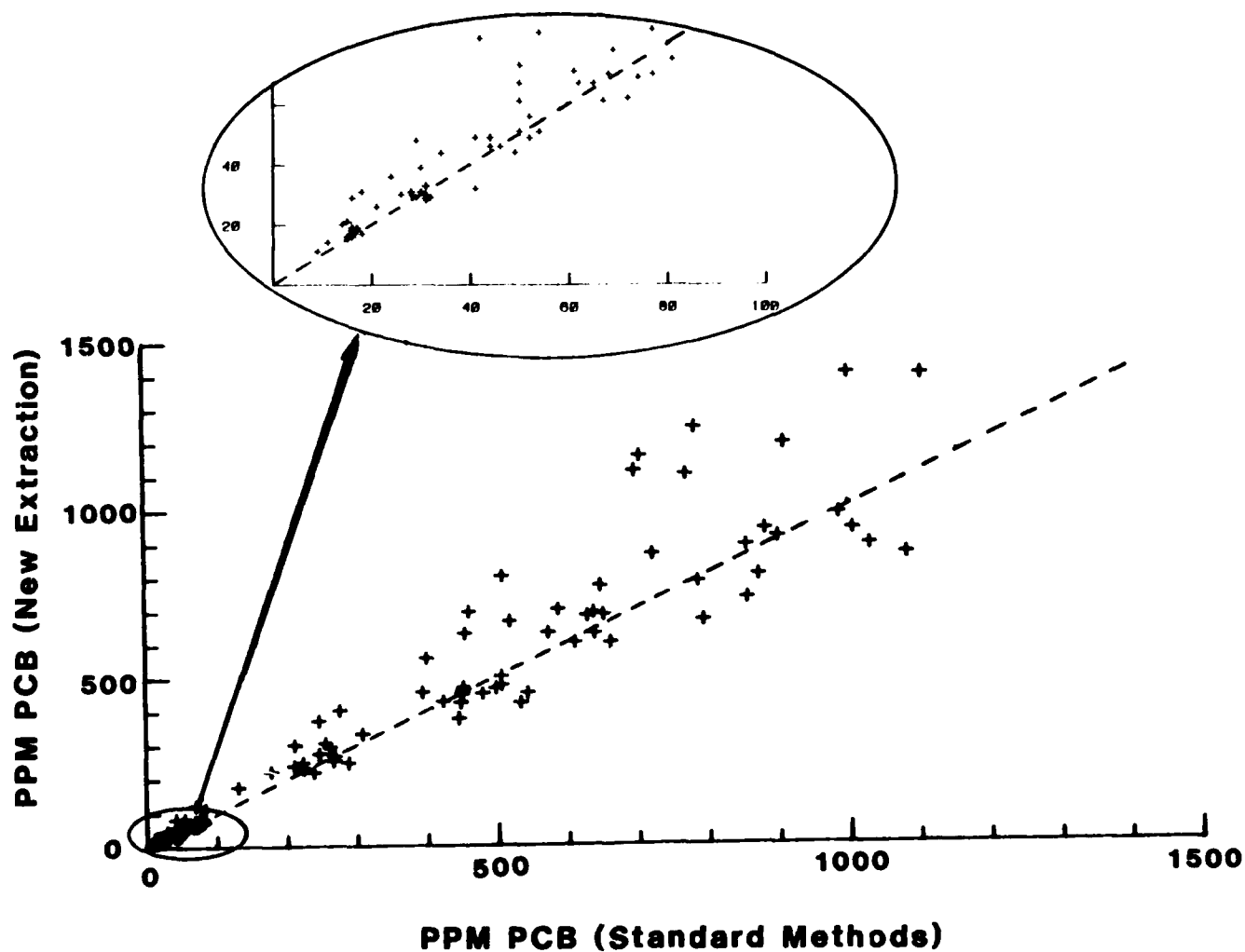


Figure 16. ESL vs Standard Laboratory Extraction.

The dashed line on the graph indicates the ideal correlation of the two methods. If the data all fell on this line, it would mean the new method extracted just as much PCB as the established laboratory technique. Although not perfect, the new method came very close to this ideal.

KIT MEASUREMENT COMPARISON

Similarly, measuring the PCB in the extract with the field kit was compared to laboratory methods. All three soil types were extracted using standard laboratory techniques and the extracts were analyzed for PCB, using both the kit and GC. The correlation of these tests is shown in Figure 17.

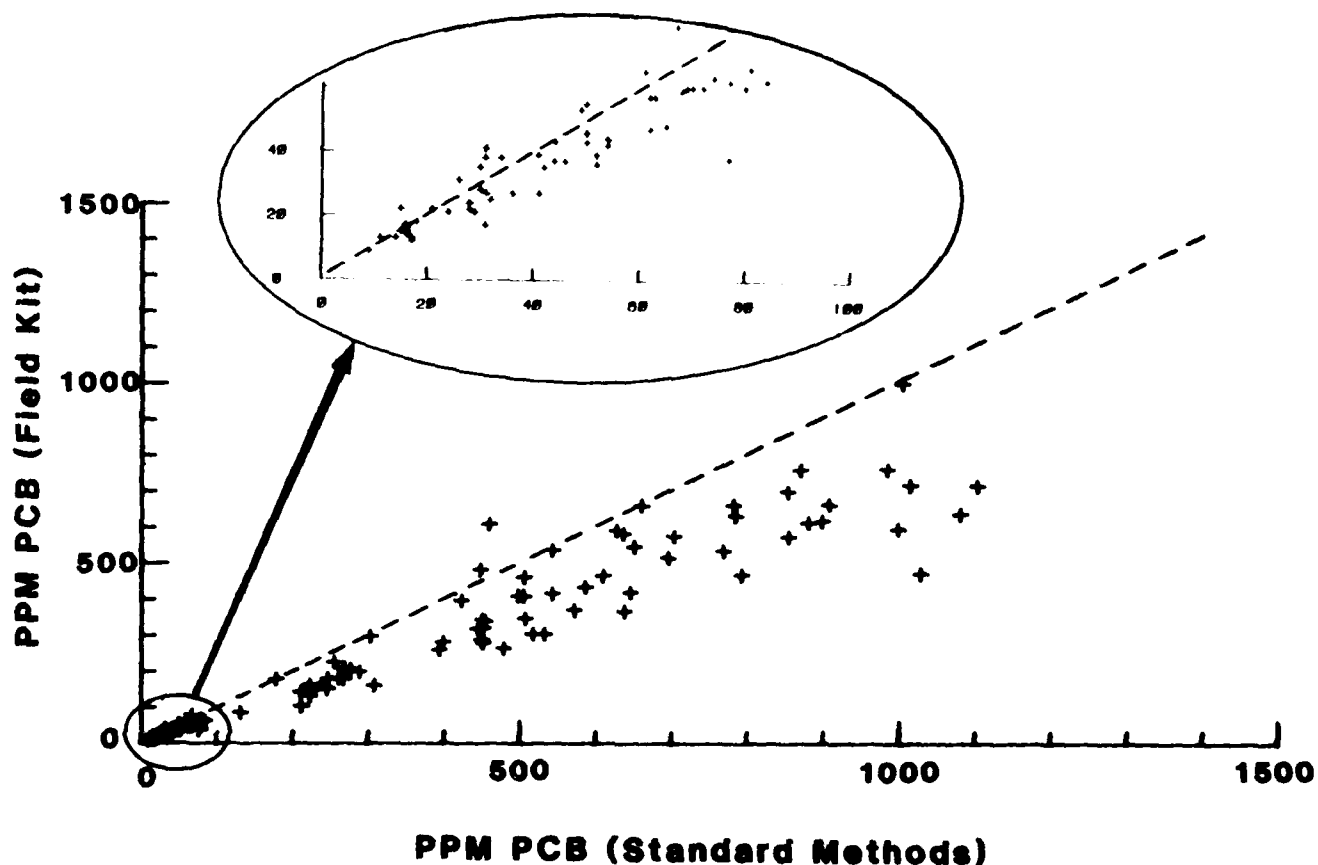


Figure 17. The PCB Field Kit vs. Standard Laboratory Methods.

Measurement of PCB with the field test kit did not correlate as well as the extraction method (i.e., the points were not as close to the dashed line); however, the points did more or less form their own line. This linear relationship would again lead to mathematically scaling the PCB measured with the field test kit.

SCALING SOIL TEST RESULTS

With respect to the entire field technique (ESL extraction combined with kit measurement) similar comparisons can be made. Before this was done however, a wheel, similar to that developed for oil testing was devised to convert the millivolt readout in an extract to a PCB concentration in soil.

In general, the millivolt answer from a soil extract is converted to a PCB concentration the oil wheel. Then this number would be multiplied by four to find the approximate soil concentration. This scaling factor of four was computed by dividing the corresponding oil concentration by the specific weight of hexane (0.667) and the minimum soil extraction efficiency (40-percent) which can be expressed as follows:

$$\frac{1}{(.667 \times 40\%)} = \frac{15}{4} \quad (\text{or approximately } 4)$$

Again, the soil wheel, shown in Figure 18, uses confidence limits; however, rather than being based on a specific type of oil, they are based on the empirical data generated in the study.

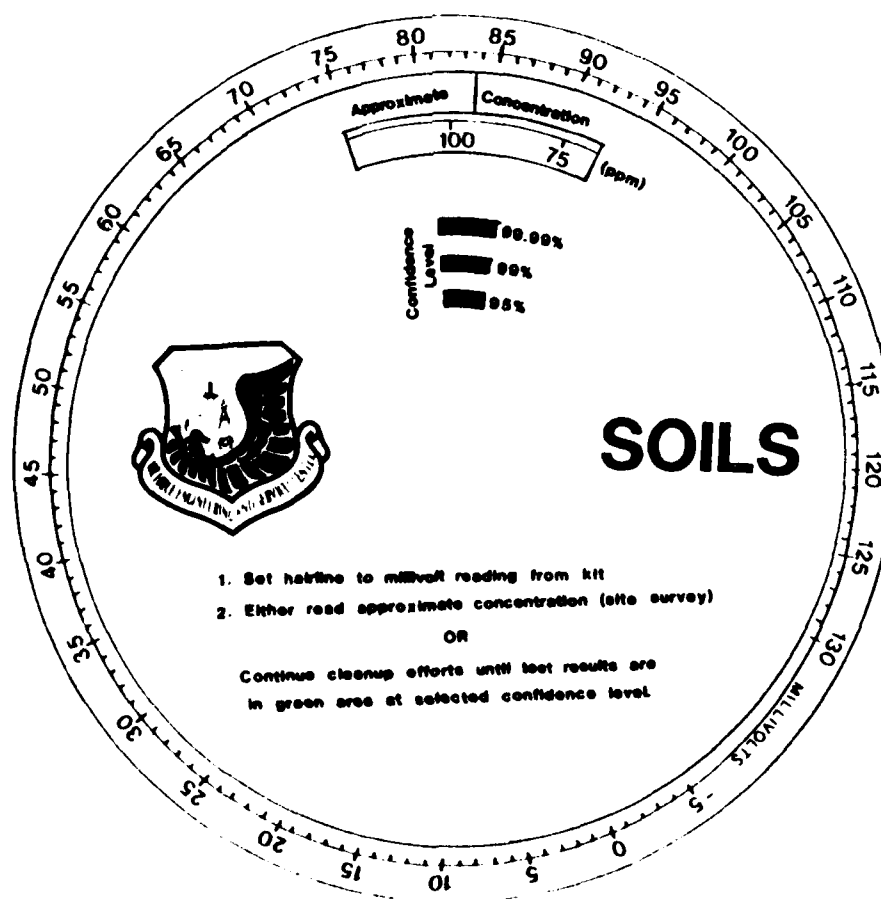


Figure 18. The ESL wheel for Converting Millivolts to a PCB Concentration in a Soil Sample.

For the operator, interpreting soil concentrations is as simple as setting the hairline to the millivolt readout and looking at the color that shows through the selected confidence limit window; red means the concentration is over 50 ppm, while green means the concentration is under 50 ppm.

FIELD/LABORATORY METHOD COMPARISON

The "approximate concentration" window was included to aid in planning cleanup actions by determining the extent of contamination. In addition, this "window" was used in comparing the new ESL field method with concentrations measured by standard laboratory techniques. Figure 19 shows this final comparison.

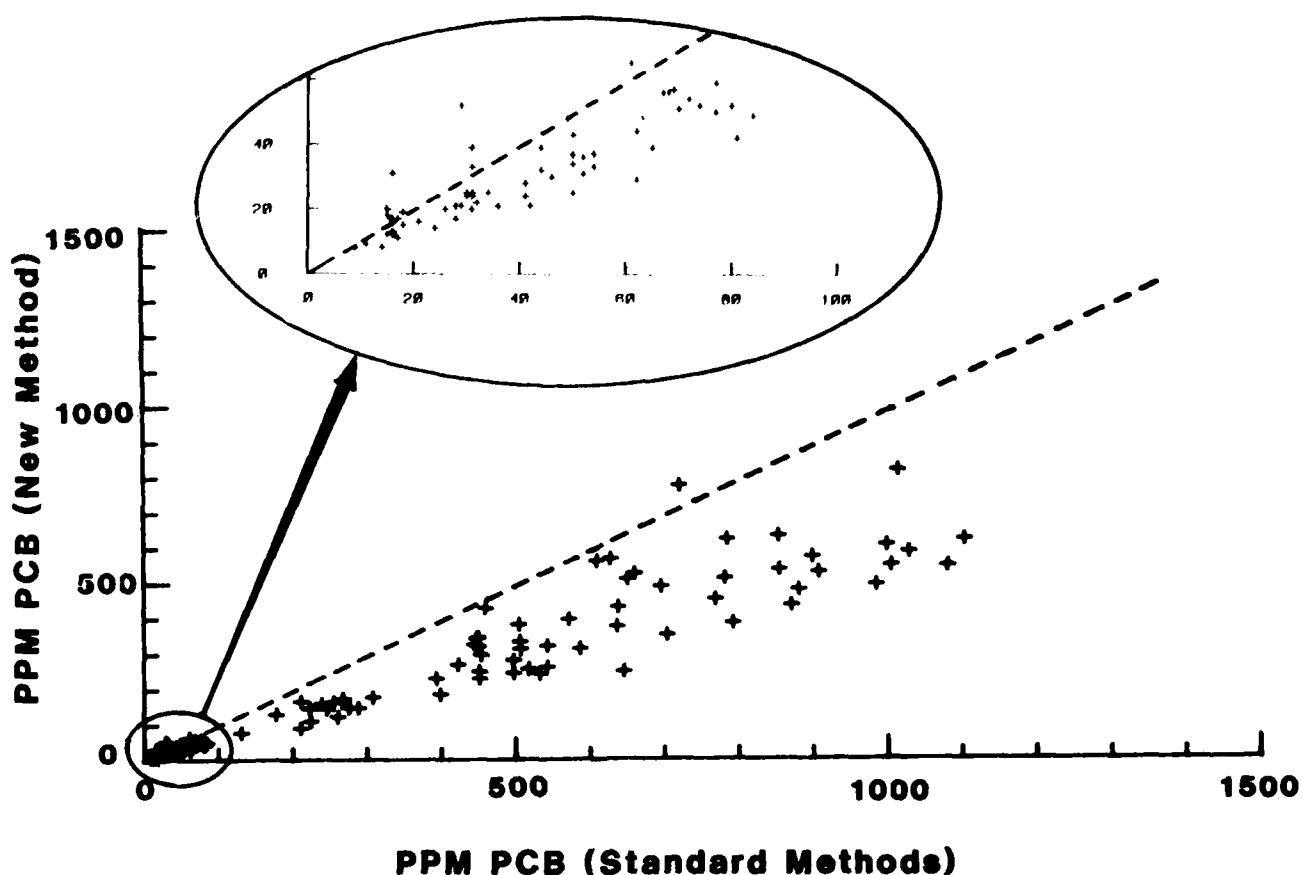


Figure 19. The ESL PCB Measurement Method vs. Standard Laboratory Techniques.

As with the field kit comparison, the data did not fall on the dashed line, but were linear, again lending to the scaling factor.

SECTION VI

FIELD EVALUATION

FIELD TEST RESULTS

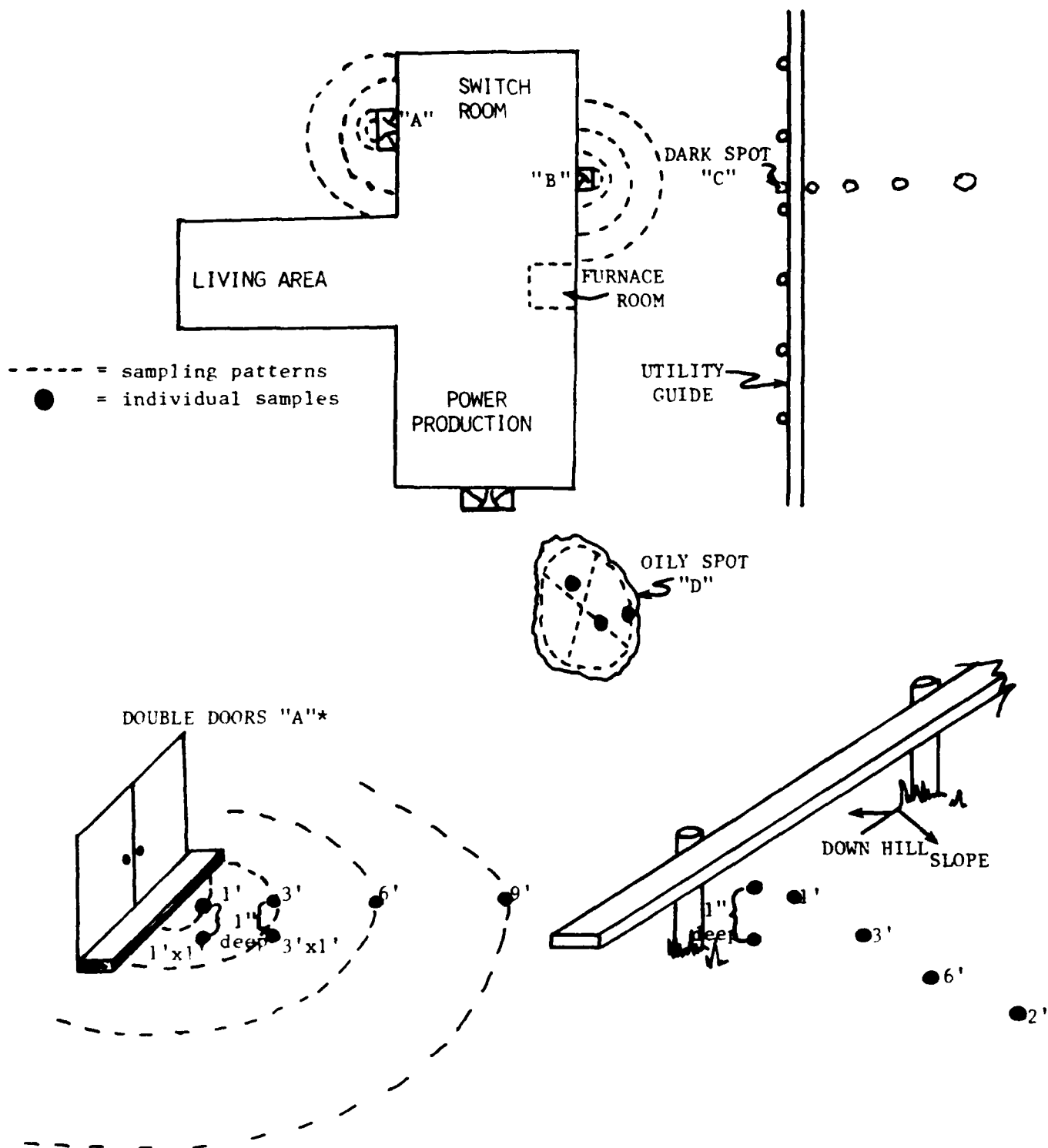
Two separate field evaluations were done at the WACS sites. The first trip refined the ESL method and established procedures for site surveys and analysis and the second trip was to train the cleanup personnel. During each trip, duplicate samples were taken to verify the kit results by laboratory analysis. One of the first sites surveyed was Bear Creek. The initial survey map, made possible by the field kit, is shown in Figure 20.

Comparing this survey map to that previously shown in Figure 2 gives an indication of the value of having the test results immediately available. The survey team was able to "zero in" on hot spots and had much more flexibility in survey protocol. This flexibility was most evident in finding and scoping the area marked "dark spot" (across from the single door to the switch room in Figure 20). This spot appeared as a darker area in the foliage and was found during a walk-around inspection of the site. It was as if someone had spilled motor oil on the ground. This area could have been found and sampled without the kit under the previous survey methods; however, the immediate feedback of the field kit enabled proper investigation. Either analyses method would have showed the dark spot positive for PCB, but because these results were known while still at the site, the area downslope from the dark spot was checked. Without the kit's on-the-spot results, it is doubtful that the downslope area would have been sampled and, as it turned out, this was one of the most highly contaminated areas.

Table 1 compares the field measurements to standard laboratory testing for the duplicate samples taken at the Bear Creek Site.

FIELD SKETCH OF BEAR CREEK WACS

17 AUG 87



*NOTE: Door "B" sampled in same manner.

Figure 20. The "PCB Map" of the Bear Creek WACS Site

TABLE 1. BEAR CREEK ANALYTICAL COMPARISON

| Sample | Description | Kit | Lab | |
|--------|---------------------------------------|------|-------|-------|
| | | mev | ppm | ppm |
| A | Switch Room Single Door 1' Out | 101 | 48 | 49 |
| B | Switch Room Single Door 3' Out | 87 | 84 | 99 |
| C | Switch Room Single Door 6' Out | 90 | 76 | 190 |
| D | Switch Room Single Door 9' Out | 86 | 88 | 150 |
| E | Switch Room Single Door 1'x 1'* | NR** | <5 | 5 |
| F | Switch Room Single Door 3'x 1' | NR | <5 | 5 |
| G | Switch Room Double Door 1' Out | 111 | 32 | 23 |
| H | Switch Room Double Door 3' Out | 114 | 28 | 16 |
| I | Switch Room Double Door 6' Out | 76 | 128 | 140 |
| J | Switch Room Double Door 9' Out | 124 | <5 | 2 |
| K | Switch Room Double Door 1'x 1' | NR | <5 | 1 |
| L | Switch Room Double Door 3'x 1' | NR | <5 | 1 |
| M | Oily Spot Near Double Door | NR | <5 | 1 |
| N | Power Room Oily Spot - 2' Dark Circle | 117 | 24 | 1 |
| O | Power Room Oily Spot - X Thru Center | 33 | 480 | 560 |
| P | Power Room Oily Spot - Circumference | 74 | 140 | 4300 |
| Q | Single Door Utility Guide - Dark Spot | -34 | 4000+ | 9700 |
| R | Single Door Utility Guide Spot x 1' | 38 | 520 | 880 |
| S | Single Door Utility Guide Spot x 3' | 33 | 480 | 15000 |
| T | Single Door Utility Guide Spot x 6' | -10 | 3600 | 3100 |
| U | Single Door Utility Guide Spot x 9' | -18 | 4000 | 4300 |

*Indicates distance out from the door x depth of the sample.

**Not Recorded - mev reading too high to be meaningful.

At first glance, the ESL method may appear too inaccurate to be useful. For example, sample "S" tested at 15,000 ppm in the laboratory while the kit indicated only 480 ppm. This may seem to be gravely underestimated, but a false negative is a sample that was classified too low. For example, if a 60 ppm sample was classified as less than 50 ppm, that would be a false negative. In the present case, the 15,000 ppm sample was still correctly categorized as "over 50 ppm." In addition, very high PCB concentrations are relatively unimportant for soil contamination. Again, the AAC was not required to make precise measurement of PCB. Since they had to remove all soil with PCB concentrations over 50 ppm, the new method was only meant to be semiquantitative at these high concentrations. If the data near 50 ppm are segregated and examined, the correlation of the field method and laboratory techniques is excellent. For example, Sample A tested within 2 percent at 48 ppm and Sample B tested within 15 percent at 100 ppm. This is the area of concern for the cleanup crews and, in turn, the area of emphasis for the kit.

An additional benefit of field screening was the analytical cost. The 21 soil samples were field-analyzed for \$105 (i.e., \$5 each). Had they been sent to the civilian laboratory in Anchorage, each sample would have cost \$140. This represented a savings of \$1835 in surveying just this one site.

If the cost of not discovering the utility guide hot spot are included, the true value of the kit becomes apparent. If this area had not been properly scoped, the cleanup crew would not have known what supplies were needed to complete the job.

As more sites were visited, more knowledge was gained as to how to better serve the cleanup crews. Because all of the Air Force communications sites were run by the same personnel (moving from site to site via reassignment), the survey techniques used at these sites hold for any other communications or radar site. Figure 21 shows the PCB map made when the North River WACS site was surveyed. (Note: Although all doors were surveyed, only door "B" is shown in the figure to indicate sampling protocol. In addition, the dimensions of the areas and sample points have been left off Figures 21 and 22 for legibility).

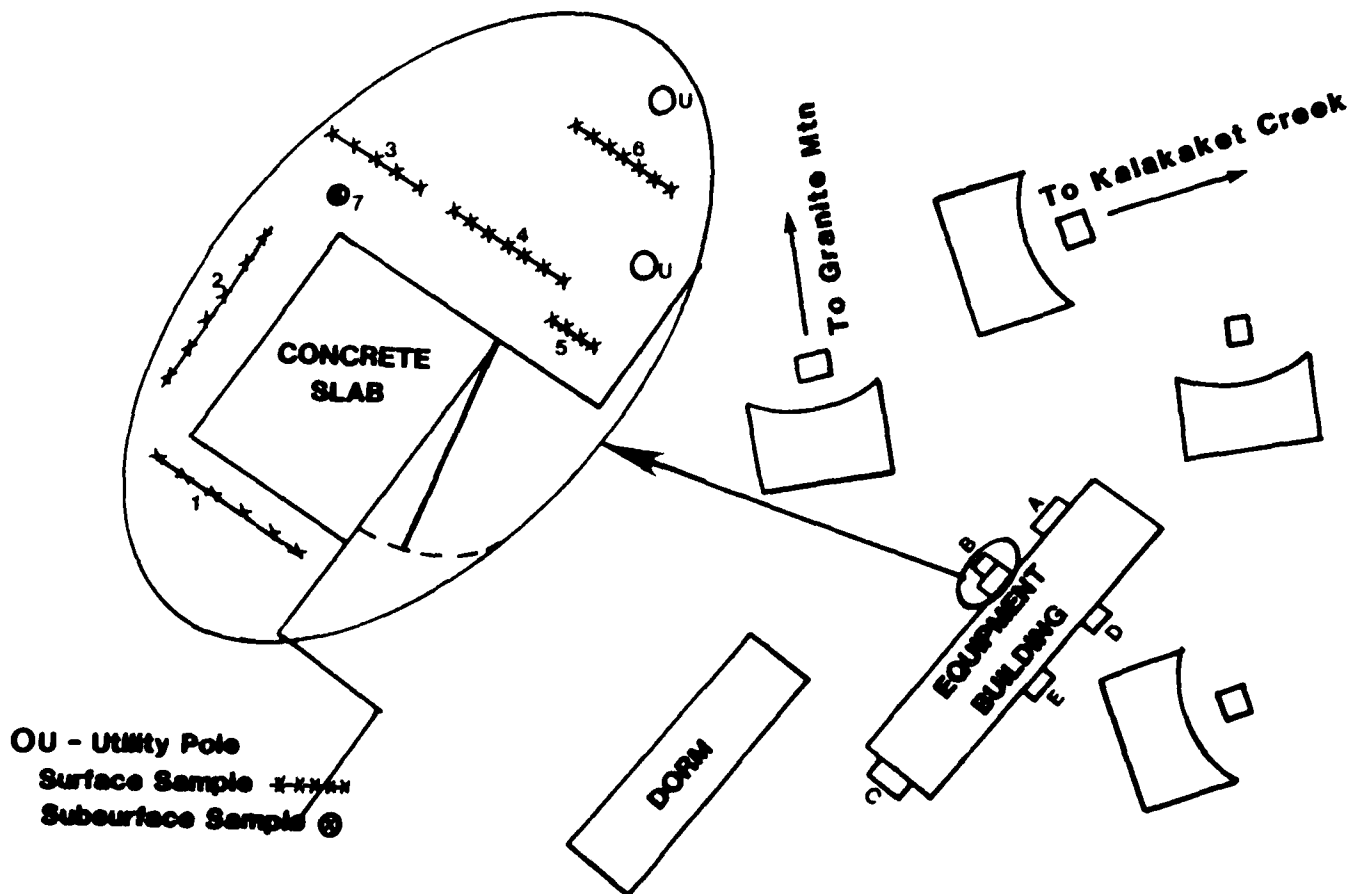


Figure 21. The North River PCB Map

As shown in the figure, the semicircular sampling patterns used at Bear Creek were abandoned for left/right/front sampling. This change was made because the data showed that crews consistently threw their waste samples in a given spot to avoid tracking the oil into the buildings. In turn, one side of a given door generally turned out to be PCB free while the other side was heavily contaminated.

In addition, more extensive testing of the individual contaminated spots was done. The aim of this survey was to provide the cleanup crew a three-dimensional map that would provide sufficient detail to compute actual volumes of soil to be removed and show the exact locations of soil to be excavated. In effect, the contaminated areas would be defined well enough to mark the excavation boundary with paint or rope and leave the cleanup crews with a clear start/stop position. Figure 22 shows this extended sampling of the hot spots.

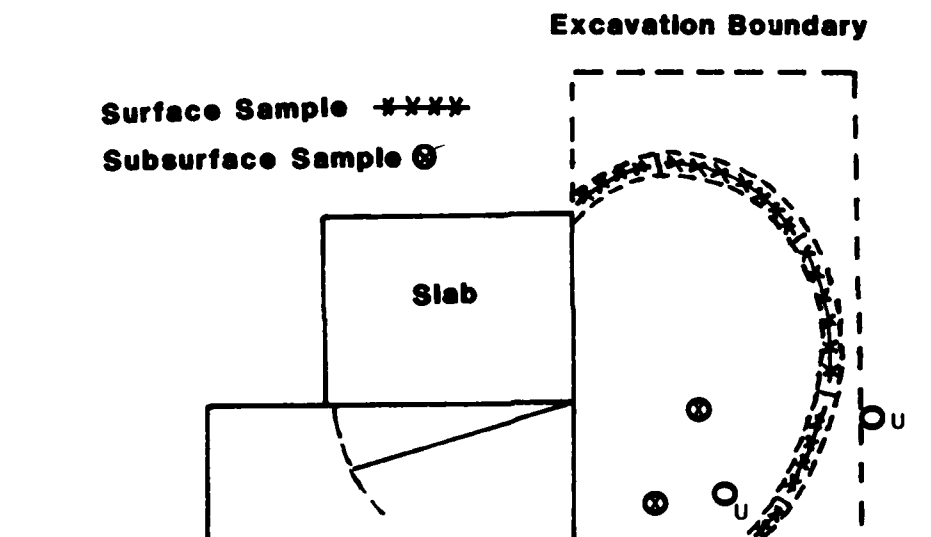


Figure 22. Final Sketch of the North River WACS Site

FIELD TESTING TECHNIQUES

By locating both the perimeter and the depth of PCB contamination (the holes were periodically sampled with depth until less than 50 ppm PCB was reached) the volumes of soil to be removed were defined. In addition, by sampling with depth, an indication of the soil/bedrock structure was established.

At this particular site, the bedrock varied between 6 inches and 3 feet around door "B." Again, this knowledge could be invaluable to the cleanup crews. For example, the information on North River meant normal cleanup equipment would be too light to accomplish the job. To better define this bedrock layer, a post-hole auger would have been an excellent tool. The auger would have accelerated the scoping procedure and more completely defined the soil conditions.

Consistent with the clean side/dirty side door discovery, a unique phenomenon was discovered at this site during the mapping; summer and winter hot spots. Referring to Figure 21, the area to the right of the door slab and just in front of the doorway (Samples 3 and 7) was the winter hot spot (a few thousand ppm contamination.) Conversely, the area behind the door to the right of the building (Sample number 5) was the summer hot spot (approximately 5 times the contamination.)

These hot spots were "dubbed" after reconstructing the site operations. Although the sites had been abandoned for years and heavily vandalized, switch rooms, office areas, repair areas, supply rooms, etc., could be identified by looking at the rubble. This knowledge led to discovering where the PCB would be located and gave logical reasons for the sampling patterns. For example, if a door led from an office area and no PCB was found, it was probably because the supervisor did not want oil samples dripped through his office, nor would he want the door opened in the winter to throw the sample out.

Consideration of the weather led to the definition of the winter and summer hot spots. In summer, and most of the year, the areas behind doors and well out of traffic areas were used for sample disposal. However, in the very cold months, the samples were quickly thrown out the door in an effort to keep the warm air in. As such, the high traffic areas were much less contaminated than the other areas. Again, site operation reconstruction led to a logical reason for the contamination found at the sites. Summer and winter hot spots can also be shown on the Bear Creek map (Figure 20). The area immediately in front of the doors was the winter hot spot and the area under the utility guide was the summer hot spot. These phenomena were common to all sites surveyed.

SECTION VII

CONCLUSIONS

The key to successfully using the PCB Field Test Kit is in recognizing what it can and cannot do. Knowing the limitations imposed by a simplified field method will ensure the best test results.

First, saying that the kit can check for PCBs in soils is actually a misnomer. What the kit can check for is chlorinated organic chemicals. Unlike gas chromatography, it cannot differentiate between chlorinated solvents and PCBs. If that is required, then standard laboratory procedures must be followed. However, in the typical cleanup scenario, nothing is lost by not identifying specific compounds. PCB sampling is not a random event. It is carefully planned and would not be done unless there was an expectation that PCB contamination would be found. For example, the WACS cleanup program was not hit or miss. The sample areas were defined and carefully laid out, based on information gathered from interviewing personnel who had been assigned to the sites and from reconstructing the operational practices when the sites were active.

Even if other chlorinated contaminants are found what are the ramifications to the PCB cleanup program? A variety of chlorinated solvents were typically used at the sites during the same time period: trichloroethylene and carbon tetrachloride for example. Since these solvents are now all classified as priority pollutants, if they were mixed with PCB in soil, they too should be removed.

The kit can serve as a field tool to help crews investigate PCB-contaminated sites. Applicable sites include remote power generation facilities, abandoned and active radar or missile sites, transformer transfer and reconditioning locations, and electrical substations to name only a few. In fact, spills can be expected anywhere PCBs were regularly handled. With the kit a field team can analyze for PCBs onsite, in 5 minutes, for \$5 or less per test. Given the safety factors that must be built into the method, there will be cases where the PCB concentration is overestimated (i.e., false positives); however, the test can be structured to eliminate false negative answers (i.e., classifying over 50 ppm PCB concentrations into clean categories). Because approximately 100 soil tests are required to survey and cleanup just one spill site, when compared to laboratory costs, the kit can pay for itself everytime it's used.

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